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NATIONAL DAM SAFETY PROGRAM. CARNEGIE LAKE DAM (NJ00150), RARIT--ETC(U)
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RARITAN RIVER BASIN
MILLSTONE RIVER
MERCER COUNTY
NEW JERSEY

LEVEL

CARNEGIE LAKE DAM

NJ 00150

PHASE 1 INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

DEPARTMENT OF THE ARMY

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

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East Orange, N.J. 07018

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Structural Analysis
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Carnegie Lake Dam, N.J.

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report cites results of a technical investigation as to the dam's adequacy. The inspection and evaluation of the dam is as prescribed by the National Dam Inspection Act, Public Law 92-367. The technical investigation includes visual inspection, review of available design and construction records, and preliminary structural and hydraulic and hydrologic calculations, as applicable. An assessment of the dam's general condition is included in the report.

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DEPARTMENT OF THE ARMY
PHILADELPHIA DISTRICT, CORPS OF ENGINEERS
CUSTOM HOUSE—2D & CHESTNUT STREETS
PHILADELPHIA, PENNSYLVANIA 19106

IN REPLY REFER TO

NAPEN-D

26 APR 1979

Honorable Brendan T. Byrne
Governor of New Jersey
Trenton, NJ 08621

Dear Governor Byrne:

Inclosed is the Phase I Inspection Report for Carnegie Lake Dam in Mercer County, New Jersey which has been prepared under authorization of the Dam Inspection Act, Public Law 92-367. A brief assessment of the dam's condition is given in the front of the report.

Based on visual inspection, available records, calculations and past operational performance, Carnegie Lake Dam, initially listed as a high hazard potential structure but reduced to a significant hazard potential structure as a result of this inspection, is judged to be in good overall condition. However, the dam's spillway is considered inadequate since 33 percent of the Spillway Design Flood - SDF - would overtop the dam. (The SDF, in this instance, is one half of the Probable Maximum Flood.) The decision to consider the spillway inadequate instead of seriously inadequate is based on the fact that overtopping of the dam would not significantly increase the hazard to loss of life downstream from that which would exist just before overtopping failure. To assure continued functioning of the dam and its impoundment, the following remedial actions are recommended to be undertaken within one year from the date of approval of this report:

a. Regrade and provide slope protection for the eroded embankment areas behind the spillway wingwalls and on the back slopes beyond the spillway abutments.

b. Repair the deteriorated concrete surfaces of the wingwalls.

c. An in-depth inspection of the concrete spillway should be initiated to minimize or lessen the future cost of additional repairs.

- NAPEN-D
Honorable Brendan T. Byrne

A copy of the report is being furnished to Mr. Dirk C. Hofman, New Jersey Department of Environmental Protection, the designated State Office contact for this program. Within five days of the date of this letter, a copy will also be sent to Congresswoman Millicent Fenwick of the Fifth District. Under the provision of the Freedom of Information Act, the inspection report will be subject to release by this office, upon request, five days after the date of this letter.

Additional copies of this report may be obtained from the National Technical Information Services (NTIS), Springfield, Virginia 22161 at a reasonable cost. Please allow four to six weeks from the date of this letter for NTIS to have copies of the report available.

An important aspect of the Dam Safety Program will be the implementation of the recommendations made as a result of the inspection. We accordingly request that we be advised of proposed actions taken by the State to implement our recommendations.

Sincerely,

JAMES G. TON
Colonel, Corps of Engineers
District Engineer

1 Incl
As stated

Copies furnished:
Dirk C. Hofman, P.E., Deputy Director
Division of Water Resources
N. J. Dept. of Environmental Protection
P. O. Box CN029
Trenton, NJ 08625

John O'Dowd, Acting Chief
Bureau of Flood Plain Management
Division of Water Resources
N. J. Dept. of Environmental Protection
P. O. Box CN029
Trenton, NJ 08625

CARNEGIE LAKE DAM (NJ00150)

CORPS OF ENGINEERS ASSESSMENT OF GENERAL CONDITIONS

This dam was inspected on 7 December 1978 by Louis Berger and Associates, Inc. under contract to the State of New Jersey. The state, under agreement with the U. S. Army Engineer District, Philadelphia, had this inspection performed in accordance with the National Dam Inspection Act, Public Law 92-367.

Carnegie Lake Dam, initially listed as a high hazard potential structure but reduced to a significant hazard potential structure as a result of this inspection, is judged to be in good overall condition. However, the dam's spillway is considered inadequate since 33 percent of the Spillway Design Flood - SDF - would overtop the dam. (The SDF, in this instance, is one half of the Probable Maximum Flood.) The decision to consider the spillway inadequate instead of seriously inadequate is based on the fact that overtopping of the dam would not significantly increase the hazard to loss of life downstream from that which would exist just before overtopping failure. To assure continued functioning of the dam and its impoundment, the following remedial actions are recommended to be undertaken within one year from the date of approval of this report:

a. Regrade and provide slope protection for the eroded embankment areas behind the spillway wingwalls and on the back slopes beyond the spillway abutments.

b. Repair the deteriorated concrete surfaces of the wingwalls.

c. An in-depth inspection of the concrete spillway should be initiated to minimize or lessen the future cost of additional repairs.

APPROVED: Joel Kellaher

JAMES G. TON
Colonel, Corps of Engineers
District Engineer

DATE: 26 April 1979

PHASE I REPORT
NATIONAL DAM INSPECTION PROGRAM

Name of Dam Carnegie Lake Dam Fed ID# NJ 00150 and NJ ID# 164

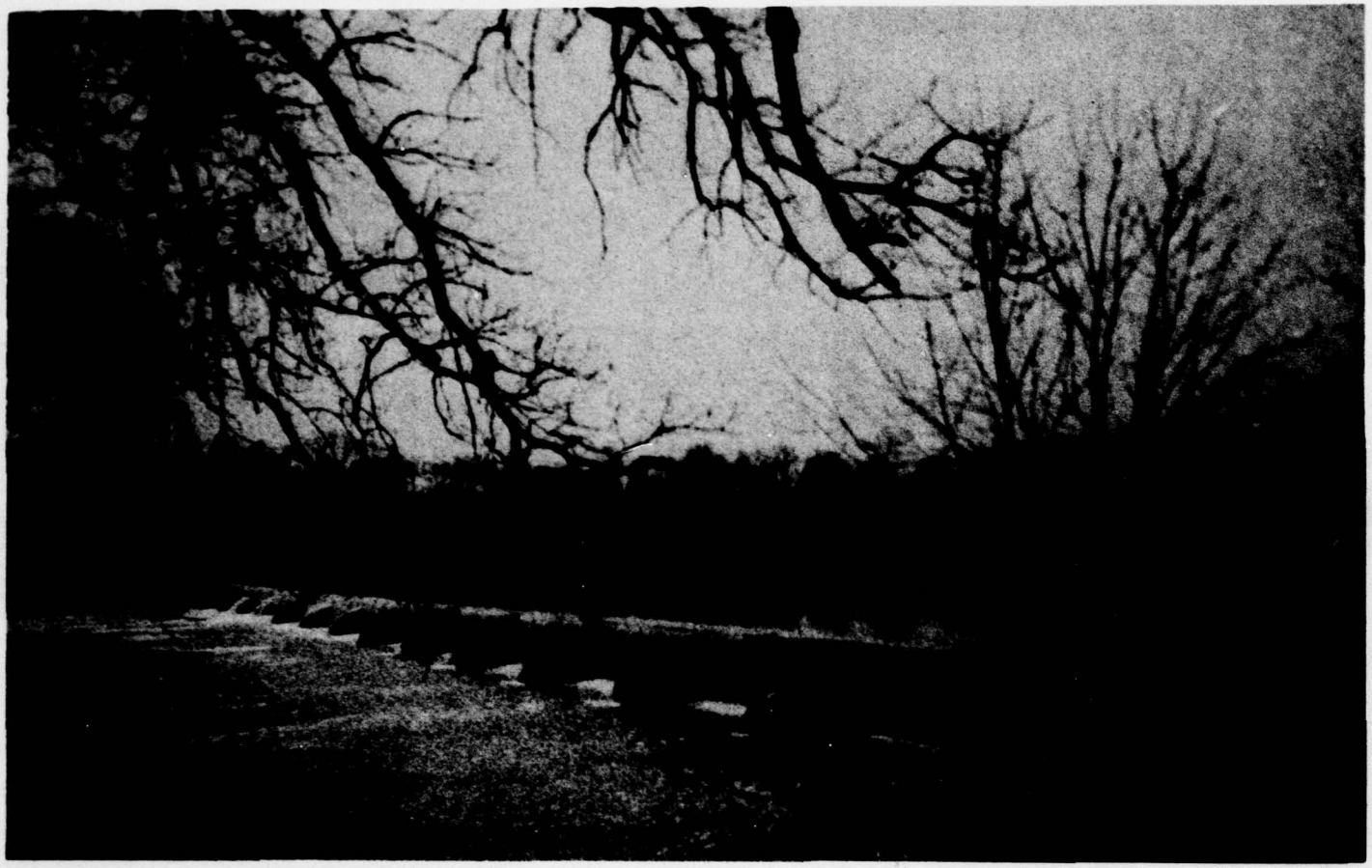
State Located New Jersey
County Located Mercer
Coordinates Lat. 4022.2 - Long. 7437.3
Stream Millstone River
Date of Inspection 7 December 1978

ASSESSMENT OF GENERAL CONDITIONS

Carnegie Lake Dam is assessed to be in an overall good condition and is recommended to be downgraded from a high to a significant hazard classification. Overtopping would not appreciably increase the danger of loss of life or property damage due to the high level of tailwater caused by natural downstream channel constrictions. No detrimental findings were uncovered to warrant further study. Recommended remedial measures to be undertaken in the future include repairing the sloughed embankment areas behind the spillway wingwalls and sandblast and patch the exposed concrete surfaces of the wingwalls.

The dam has an inadequate spillway capacity, being able to accommodate only 16% of a full PMF.

F. Keith Jolls P.E.
Project Manager



OVERVIEW OF CARNEGIE LAKE DAM

DECEMBER, 1978

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PREFACE

This report is prepared under guidance contained in the Recommended Guidelines for Safety Inspection of Dams, for Phase I Investigations. Copies of these guidelines may be obtained from the Office of Chief of Engineers, Washington, D.C. 20314. The purpose of Phase I Investigation is to identify expeditiously those dams which may pose hazards to human life or property. The assessment of the general condition of the dam is based upon available data and visual inspections. Detailed investigation, and analyses involving topographic mapping, subsurface investigations, testing, and detailed computational evaluations are beyond the scope of a Phase I investigation; however, the investigation is intended to identify any need for such studies.

In reviewing this report, it should be realized that the reported condition of the dam is based on observations of field conditions at the time of inspection along with data available to the inspection team. It is important to note that the condition of a dam depends on numerous and constantly changing internal and external conditions, and is evolutionary in nature. It would be incorrect to assume that the present condition of the dam will continue to represent the condition of the dam at some point in the future. Only through continued care and inspection can there be any chance that unsafe conditions be detected.

Phase I inspections are not intended to provide detailed hydrologic and hydraulic analyses. In accordance with the established Guidelines, the Spillway Test flood is based on the estimated "Probable Maximum Flood" for the region (greatest reasonably possible storm runoff), or fractions thereof. The test flood provides a measure of relative spillway capacity and serves as an aide in determining the need for more detailed hydrologic and hydraulic studies, considering the size of the dam, its general condition and the downstream damage potential.

PHASE I INSPECTION REPORT
NATIONAL DAM INSPECTION PROGRAM
NAME OF DAM: CARNEGIE LAKE DAM FED NJ #00150 NJ ID #164

SECTION 1 - PROJECT INFORMATION

1.1 GENERAL

a. Authority

This report is authorized by the Dam Inspection Act, Public Law 92-367, and has been prepared in accordance with Contract FPM-36 between Louis Berger & Associates, Inc. and the State of New Jersey and its Department of Environmental Protection, Division of Water Resources. The State, in turn, is under agreement with the U.S. Army Engineer District, Philadelphia, to have this inspection performed.

b. Purpose of Inspection

The purpose of this inspection is to evaluate the structural and hydraulic condition of Carnegie Lake Dam and appurtenant structures, and determine if the dam constitutes a hazard to human life or property.

1.2 DESCRIPTION OF PROJECT

a. Description of Dam and Appurtenances

Carnegie Lake Dam is a 724' long, straight concrete wall and buttress structure with a 575' spillway four feet wide at the crest. In the center of the spillway, there is a 193-foot long vee-notched weir which has a center depth of 0.7 foot. Twenty 4' x 8' concrete buttresses on 28' centers brace the vertical wall along the downstream face of the spillway and extend from the crest elevation (+53.2 MSL) down to approximate elevation +24 where the buttresses are founded in the underlying shale. The upstream vertical face is protected by an interlocking steel sheet piling which also extends to bedrock. The sheeting is secured

to the concrete wall by 12-inch thick tremie-placed reinforced concrete. The right end of the spillway terminates at a concrete sluice gate structure which extends roughly 95 feet to the east abutment adjacent to the towpath of the Delaware-Raritan Canal. The gate structure contains two 36" diameter C.I. pipes at elevation +42.2. The left end of the spillway terminates at a concrete abutment which extends 54 feet to the natural bank along the westerly shoreline.

b. Location

Carnegie Lake Dam is located on the Millstone River, a tributary of the Raritan River, northeast of the Borough of Princeton in South Brunswick Township, Mercer County, New Jersey, and is approximately 1,200 feet south of the Route 27 bridge over the river.

c. Size Classification

Carnegie Lake Dam is 28 feet high and impounds 5,326 acre-feet of water at maximum elevation. Based on the Guidelines for Safety Inspection of Dams, this dam is in the intermediate size category (total storage $\geq$ 1000, $<$ 50,000 AF).

d. Hazard Classification

Carnegie Lake Dam was initially classified as high hazard but as a result of this inspection, is recommended to be downgraded to a significant hazard classification. Only the downstream Kingston Mill Dam, a small number of inhabitable and commercial structures would be affected should Carnegie Lake Dam fail. The new highway bridge on Route 27 is built well above flood water elevation and in all probability could withstand a design frequency flood. A failure of the study dam however, could interrupt traffic on Route 27 by overtopping the roadway embankment.

e. Ownership

Carnegie Lake Dam is owned by Princeton University, Princeton, New Jersey 08540.

f. Purpose of Dam

Carnegie Lake Dam is used for recreational purposes.

g. Design and Construction History

No records pertaining to the initial design and construction of Carnegie Lake Dam are immediately available. According to University personnel, it was constructed during the early part of the century. In 1930, the combined firms of F.S. Tainter and Parsons, Klapp, Brinckerhoff & Douglas, Consulting Engineers, prepared plans for the reconditioning of the dam but it is unknown to what extent these modifications were implemented. In 1966, Praeger-Kavanagh-Waterbury, Consulting Engineers, also prepared plans for the repair work which was accomplished that summer. Additionally, dredging of the lake was undertaken and completed in 1974 by the American Dredging Company.

h. Normal Operating Procedures

The dam is operated by Princeton University plant engineering personnel. Due to the extremely wide spillway, the dam operates principally as an uncontrolled spillway. (See Section 4).

1.3 PERTINENT DATA

a. Drainage Area

The drainage area of Carnegie Lake Dam consists of 159.1 square miles of lightly developed, gently rolling terrain.

b. Discharge at Damsite

Maximum known discharge: Unknown

Spillway capacity at normal pool elevation - 120 cfs (vee-notched weir).

Total spillway capacity at maximum pool elevation - 14,420 cfs

c. Elevation (ft. above MSL)

Top Dam - +57.2
Recreation pool - +53.2 (Top of spillway)
Streambed at centerline of dam - 39±

d. Reservoir

Length of maximum pool - 29,900 feet
Length of recreation pool - 17,600 feet

e. Storage (acre-feet)

Top of dam - 5,326 acre-feet
Recreation pool - 1,344 acre-feet

f. Reservoir Surface (acres)

Top dam - 1,746 acres
Recreation pool - 245 acres

g. Dam

Type - Concrete, narrow-crested wall and buttress
Length - 724 feet
Avg. total structural height - 28± feet
Top Width - 4.0 feet
Side Slopes - Vertical on spillway, 2H:1V at abutments
Cutoff - Steel sheeting to bedrock (upstream face)
Grout curtain - None

h. Diversion and Regulating Tunnel

Type - None

i. Spillway

Type - Narrow crested weir
Length of weir - 575 feet, with 193' vee-notch at center (depth = 0.7')
Crest elevation - +53.2 MSL
Gates - None
U/S Channel - Main body of lake
D/S Channel - Main body of Kingston Mill Dam reservoir

j. Regulating Outlets

2 - 36" dia. C.I. pipes (inv. El. + 42.2)

SECTION 2 - ENGINEERING DATA

2.1 DESIGN

The information available for review for the Carnegie Lake Dam consisted of:

1) Two drawings of 1930 reconditioning by F.S. Tainter & Parsons, Klapp, Brickerhoff & Douglas, Consulting Engineers.

2) Dam Applications Nos. 164 & 164 R, State Division of Water Policy and Supply, 1966 (and various correspondence).

3) Two construction drawings dated 1966, prepared by Praeger-Kavanagh-Waterbury, Consulting Engineers.

4) Five sheets of spillway capacity calculations, dated 1966, by Praeger-Kavanagh-Waterbury, Consulting Engineers.

5) One sounding plan of the lake bottom (taken after dredging) dated 1974, prepared by the American Dredging Company.

Item 3 above depicted the overall configuration of the dam and the 1966 remedial repairs. Although no design analyses (except for the spillway hydraulics) were available, a good overview of the dam geometry was afforded the inspection team. Five widely spaced boring logs were included in the plans which indicated the depth to the underlying rock and the composition of the medium to coarse sand and gravel overburden. The overburden soils in this area are recent alluvium composed mostly of sands, silts and some clay and are quite variable in composition. The underlying rock is composed of a black shale interbedded with Lockatong orgillite. The top surface has a decomposed layer.

2.2 CONSTRUCTION

Nothing is known about the construction except the 1966 work was accomplished substantially in accordance with the contract plans. This rather

extensive repair work obliterated all evidence of any earlier repairs.

2.3 OPERATION

Hydraulically, the dam appears to be operating satisfactorily as an uncontrolled weir. The 1966 renovation work appears to have arrested further deterioration of the buttresses below the spillway.

2.4 EVALUATION

a. Availability

Sufficient engineering data is available to assess the structural stability. No data was located to indicate the composition of the short embankment zones at each end of the spillway but in view of the geometry, this was of minor concern to the inspection team. Additionally, from the wingwall geometry, a concrete cut-off wall may extend all the way past the abutment but this could not be verified.

b. Adequacy

The field inspection and review of available design plans reveal that the dam is structurally sound and in spite of its age, is in a well-built condition. It is felt that adequate data was available to render the enclosed assessment contained in Sections 6 and 7 without recourse to gathering additional information.

c. Validity

The validity of the available data is not challenged and is accepted without recourse to further investigations.

SECTION 3 - VISUAL INSPECTION

3.1 FINDINGS

a. General

The on-site inspections were conducted on December 7 and 29, 1978 and revealed the dam to be in an overall good condition. Following a period of heavy rain, the dam site was revisited on January 24 and again on February 8, 1979. As can be seen from the attached 24 January photographs, the entire flood plain was heavily inundated and the spillway practically submerged. It was noted that the downstream flow was not restricted by either the Route 27 or the old Kings Highway bridge but that the tailwater under the Route 27 structure backed up to the old (circa 1798) stone arch bridge immediately above Route 27. The Kingston Mill Dam immediately above the bridges was completely submerged by over 6 feet of water.

b. Dam

The straight walled spillway structure is in excellent alignment and the wide vee-notched weir was flowing freely at the time of the earlier inspections. The exposed concrete surfaces at the spillway piers and retaining walls exhibits numerous spalled and chipped areas with some efflorescence noted at the construction joints. The size of the piers and buttresses along the spillway indicates a massive gravity-type design. The 1966 repair work appears to be in good condition with only minor surface crazing and chipping. Severe horizontal cracks were observed at the left wingwall and a portion of the top slab has broken off. The embankment sections behind the spillway piers are in good condition but surface erosion was observed behind both downstream wingwalls and there are numerous trees on the backslopes. The left abutment backslope has eroded to roughly a 1:1 slope exposing a hard argillite-type shale at the footing elevation. The right abutment keys into the

embankment of the Delaware and Raritan Canal towpath which parallels the east shore of Carnegie Lake. The water level in the lake and canal appeared to be nearly equal at the time of the second inspection but downstream from the study dam, there are several small lateral outlets from the canal into the river. The towpath below the dam appears to have a concrete corewall. Although the lake and canal are in close proximity, their water levels are basically independent.

c. Appurtenant Structures

Two 36-inch sluice gates are located near the right abutment and have an invert that is roughly 11 feet below spillway crest. The gates were submerged and could not be observed. According to University officials, they are operable and in satisfactory condition. There is minor surface cracking and spalling on the gate structure but the top slab is in good condition (as a result of the 1966 refurbishing). There is an ice-reduction aeration device located at the left abutment but the controls have been recently vandalized and it appeared to be presently inoperative. However, University officials stated that they plan to have it repaired.

d. Reservoir Area

Carnegie Lake extends over three miles to the south to its head waters at the Penn-Central Railroad trolley line into Princeton. The lake is 300 to 800 feet wide and was dredged to depths of 6 to 8 feet by the American Dredging Company five years ago to facilitate the collegiate sailing and crew events that are held by the University. The upper reaches of the lake are fed by Stony Brook with the Millstone River entering the reservoir from the east about one mile further to the north. (The canal is carried over the river in a flume). The entire east bank is formed by the canal towpath and the west bank gently slopes up to the adjacent residential neighborhoods. The lake is well-maintained and clear of major debris.

e. Downstream Channel

Immediately below the spillway, the Millstone River bifurcates and flows north approximately 1,000 feet where it passes over the narrow, low Kingston Mill Dam before being bridged by the Kings Highway revolutionary-period stone arch bridge (now basically abandoned) and the new (1965) Route 27, two span steel stringer bridge. Additionally, there is a small timber bridge under Kings Highway and a large (12'x6'+) elliptical arch relief culvert under Route 27 (between the main channel and the canal). These serve as relief structures for the main channel spans. As noted in 3.1.a, the river is impeded further downstream by the rather narrow natural banks and during periods of heavy flow, the rather wide flood plain just below the dam and Kings Highway embankment are overtopped (see photographs of the 24 January flooding). The right bank is formed by the D&R Canal dike while the slopes on the left bank rise rather steeply to higher surrounding terrain. The Route 27 alignment is above the flood elevation but there are a few residences and commercial properties located in lower lying areas immediately along the river bank and it is conceivable that the easterly portion of the road embankment could be overtopped in extreme flooding.

SECTION 4 - OPERATIONAL PROCEDURES

4.1 PROCEDURES

Operational procedures are conducted by personnel from the Princeton University maintenance department. The sluice gates are reportedly operable although they have not been utilized since the lake was dewatered for repair of the dam in 1966. The gate controls are locked to prevent vandalism. Since the lake is used only for recreational purposes and the sluice gate capacity is small when compared to the spillway capacity, there is little occasion to attempt to control the lake level with the sluice gates.

4.2 MAINTENANCE OF DAM

The dam is maintained by University personnel on an as-needed basis. Inspections are conducted after major storms and seasonally by maintenance crews responsible for the protective aeration system located along the upstream face of the dam. Personnel of the University's athletic teams, which utilize the lake daily in season, notify the maintenance department of any deficiencies or debris in the lake. Vegetative growth is reduced by use of yearly herbicidal treatments and a groundskeeper maintains the shoreline and abutments adjacent to the dam.

4.3 MAINTENANCE OF OPERATING FACILITIES

The only operating facilities at Carnegie Lake Dam are the two 36" diameter C.I. pipes at the east abutment. These are periodically inspected and maintained but as previously stated, are not employed on a day-to-day basis.

4.4 DESCRIPTION OF WARNING SYSTEM

No warning system exists except for monitoring by university personnel and municipal police during major storms.

4.5 EVALUATION

The existing operational and maintenance procedures and safeguards during major storms are considered adequate for the following reasons:

- The dam has been overtopped several times in the past but, since it is a relatively massive concrete structure apparently has suffered little or no damage.
- The downstream channel experiences high backwater from downstream constrictions which essentially diminishes the dam's function to one of a submerged weir during periods of extremely heavy flows. (See Section 5).
- The primary purpose of the lake and dam preclude any additional operational procedures other than those now in practice.

SECTION 5 - HYDRAULIC/HYDROLOGIC

5.1 EVALUATION OF FEATURES

a. Design Data

In accordance with the criteria in the Recommended Guidelines for Safety Inspection of Dams, it has been determined that the dam at Carnegie Lake is intermediate in size and in the significant hazard category. Accordingly the spillway design flood (SDF) was determined by the inspecting engineer to be ½ the probable maximum flood (PMF). The inflow hydrograph was calculated using precipitation data from Hydrometeorlogical Report #33. The inflow hydrograph and flood routing were performed utilizing the HEC-1 computer program. Peak inflow to the reservoir for the ½ PMF was 55,720 cfs, and when routed through the reservoir, was reduced to 45,650 cfs. The spillway capacity before overtopping occurs is approximately 14,420 cfs. Therefore, the spillway will accommodate only 32% of the SDF. This flood would cause the dam to be overtopped by approximately 8 feet. The spillway is therefore inadequate.

b. Experience Data

Carnegie Lake Dam was designed to accommodate a 50-year flood which was estimated to have a peak of 13,550 cfs (Dam Application No. 164). According to local information, the dam has been overtopped numerous times, as evidenced by the presence of erosion on the downstream embankment. There are no streamflow records available. Although the 1966 repair plans provide for the emplacement of a water level gage at each abutment, these recorders were not observed in the field.

c. Visual Observations

A third visual inspection was made on January 24, 1979 following an unusually heavy rainstorm. The dam appeared to be functioning in a satisfactory condition

with the tailwater approximately one foot below the crest (the buttresses were almost entirely submerged). The dam had apparently transmitted the storm without overtopping. The downstream Kingston dam, was completely inundated and the high water reached the arch soffits of the Kingston Bridge. However, this bridge does not appear to be the primary constriction, as water was at approximately the same elevation on each face. According to University personnel the major constriction lies further downstream and appears to be a narrowing of the stream channel between higher banks. Unofficial records report the tailwater elevation is at times as high as 2 feet over the Carnegie Dam spillway, hence the spillway capacity has little actual influence on the overall hydraulic situation during periods of extreme flooding.

d. Overtopping Potential

There are indications and a verbal history that the dam has been repeatedly overtopped. Moreover, the hydraulic analyses substantiates that the spillway is inadequate to accommodate the design flood. Therefore, the potential for overtopping remains considerable but referring to the previous paragraph, overtopping would have little effect on the dam itself and the downstream flooding problem appears to be little influenced by the hydraulic condition at Carnegie Lake.

e. Drawdown Potential

Drawdown of Carnegie Lake would take approximately 18 days assuming the sluice gates are operating at full capacity and there is no tailwater condition. This time is based on a nominal inflow of 1 cfs per square mile. However, if a tailwater of only 5 feet is assumed, drawdown will not take place, as inflow to the reservoir will be greater than outflow.

SECTION 6 - STRUCTURAL STABILITY

6.1 EVALUATION OF STRUCTURAL STABILITY

a. Visual Observation

Based upon the field inspection, the structural stability of Carnegie Lake Dam is believed to be satisfactory. The 1966 rehabilitation work has prevented further deterioration to the spillway wall counterforts and the full width upstream line of MP115 steel sheeting (driven into the shale foundation) greatly reduces any potential danger to overturning or sliding failure. Additionally, the 1974 dredging relieves excessive earth pressure against the upstream face. The condition of the exposed concrete requires surficial repairs but this can be done under the University's normal maintenance program. The short embankment zones at each abutment should be regraded on the backslopes and brought up to the elevation of the spillway end piers. In view of the overtopping potential and the relatively short embankment lengths at each end, it might be prudent to protect the entire backslope which would preclude future erosion and repair costs. The only element that could not be observed closely was the condition of the downstream channel immediately below the vee-notched weir in the center. However, this appears to be of minor concern as the borings indicate that the top of the shale is at or very close to the streambed elevation.

b. Design and Construction Data

Summarizing Section 2, little is actually known regarding the design assumptions but the 1930 and 1966 plans indicate that the dam is founded on the underlying shale bedrock and this is substantiated by the lack of tilting or differential settlement. Under the context of this study phase, additional design data was not believed to be necessary to assess the structural stability.

c. Operating Records

Written operating records are non-existent but the dam has functioned satisfactorily from a hydraulic standpoint since its construction some 80 years ago. The previously repaired ice-damage and deterioration to the tops of the buttresses are of little structural consequence.

d. Post Construction Changes

There have been no further structural modifications since the 1974 dredging operation but the abutment backslopes have apparently been allowed to erode for a considerable length of time.

e. Seismic Stability

Carnegie Lake Dam is located in Zone 1 and experience reveals that dams in the zone will have adequate stability under dynamic loading conditions if stable under static loading conditions.

SECTION 7 - ASSESSMENTS/RECOMMENDATIONS/ REMEDIAL ACTIONS

7.1 DAM ASSESSMENT

a. Safety

Subject to the inherent limitations of the Phase I visual inspection, the Carnegie Lake Dam is judged to be in an overall sound structural condition but the spillway has insufficient capacity and can discharge only 32% of the design flood of ½ PMF. The embankment crest of the dam on either side of the wide spillway is overtopped by approximately 4 feet for this design flood but it is felt that the dam can safely stand such overtoppings. Although the spillway is inadequate, the dam is not assessed as unsafe as failure from overtopping would not significantly increase the hazard to loss of life downstream from the dam from that which would exist just before overtopping failure. Little can be envisioned to effectively alleviate the overtopping potential during heavy storms. Further, due to natural hydraulic restrictions further downstream, flood tailwater elevations tend to submerge the dam crest so that its theoretical spillway capacity is irrelevant during periods of extreme floods.

b. Adequacy of Information

The information made available by Princeton University is deemed to be adequate regarding the analyses of safe operation and structural stability.

c. Urgency

No urgency is attached to implementing any further studies or the remedial measures set forth below.

d. Necessity for Further Study

In view of the hazard classification of this dam, its overall condition and the fact that

it is continually monitored by trained engineering personnel, additional inspections under the purview of P.L. 92-367 are deemed to be unnecessary. The University maintains an internal system of periodic inspections and emergency action plans which basically reflects the requirements mandated under the National Dam Inspection Act. Further, their continuity of action is not contingent upon external funding and bureaucratic considerations.

7.2 RECOMMENDATIONS/REMEDIAL MEASURES

a. Alternatives

- It is recommended that the eroded embankment areas behind the spillway wingwalls be backfilled and covered with slope protection; especially in the areas immediately adjacent to the wingwalls. Similarily, the remaining eroded areas on the back slopes beyond the spillway abutments should be backfilled and replanted.

- The deteriorated exposed concrete surfaces of the wingwalls should be sand blasted and resurfaced with gunite or epoxy mortar.

b. O&M Maintenance and Procedures

No additional procedures other than those currently in effect appear to be warranted in view of the above assessment. However, in the future, an in-depth inspection of the concrete spillway should be undertaken (in the form of preventative maintenance) to minimize or lessen the future cost of additional repairs.

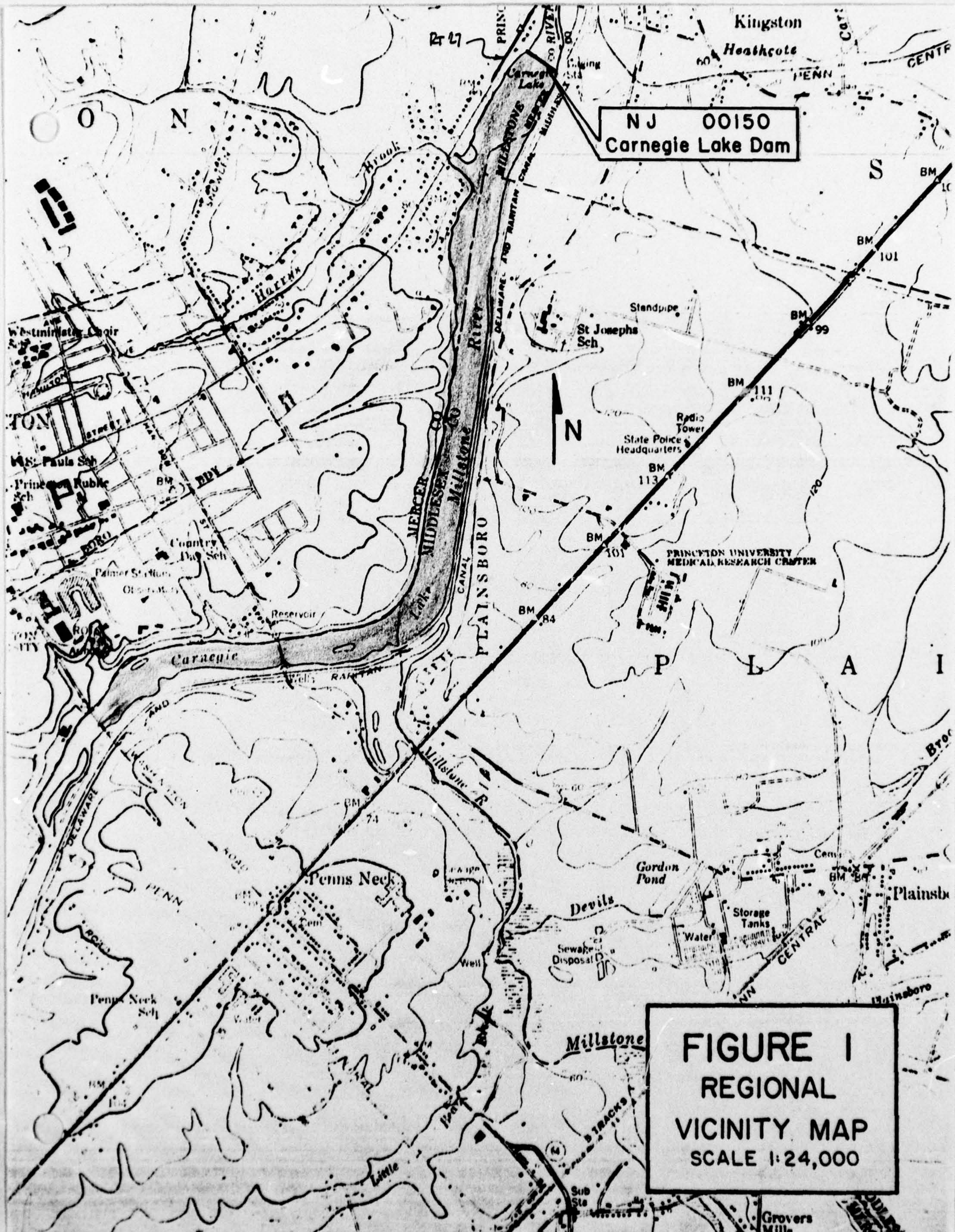
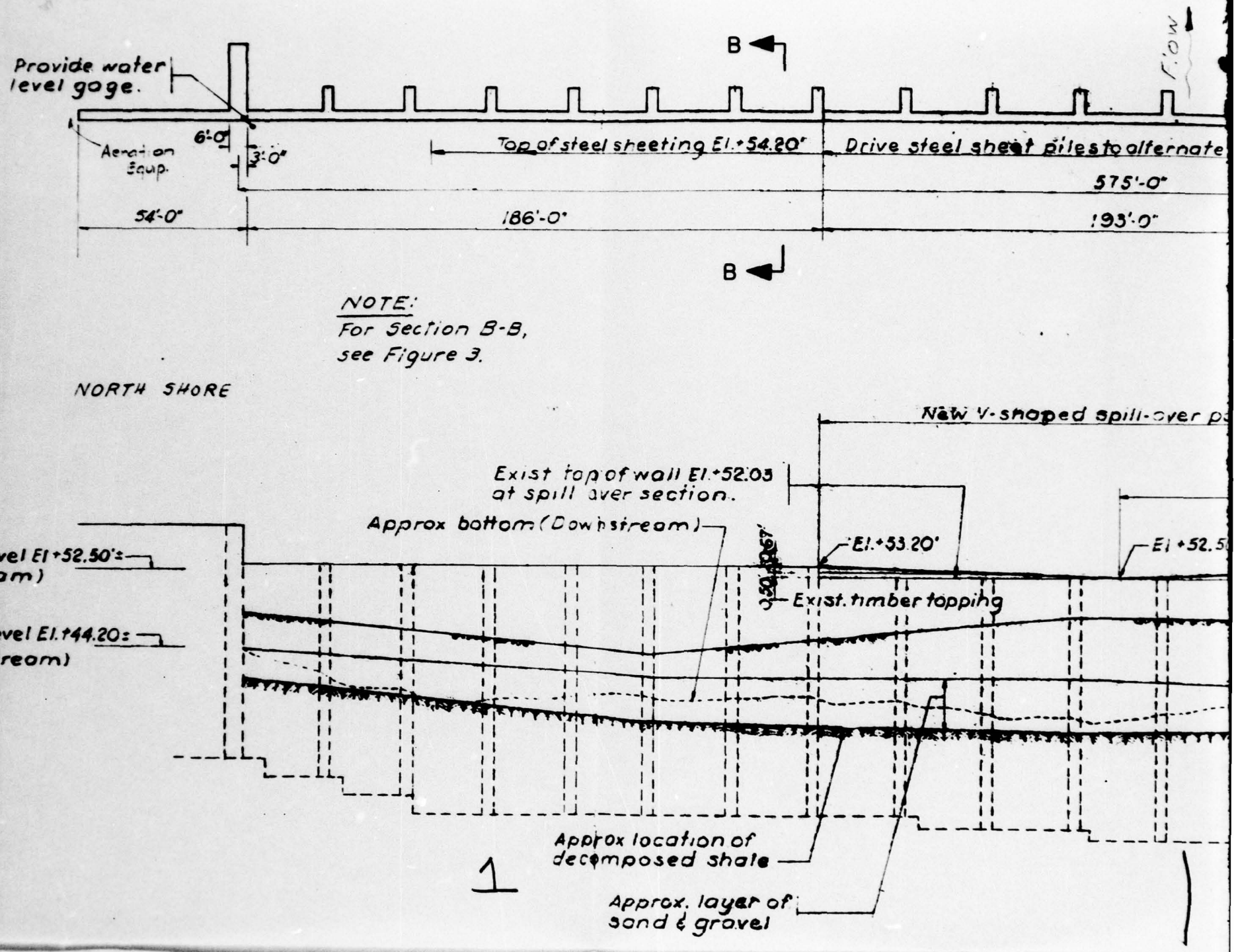
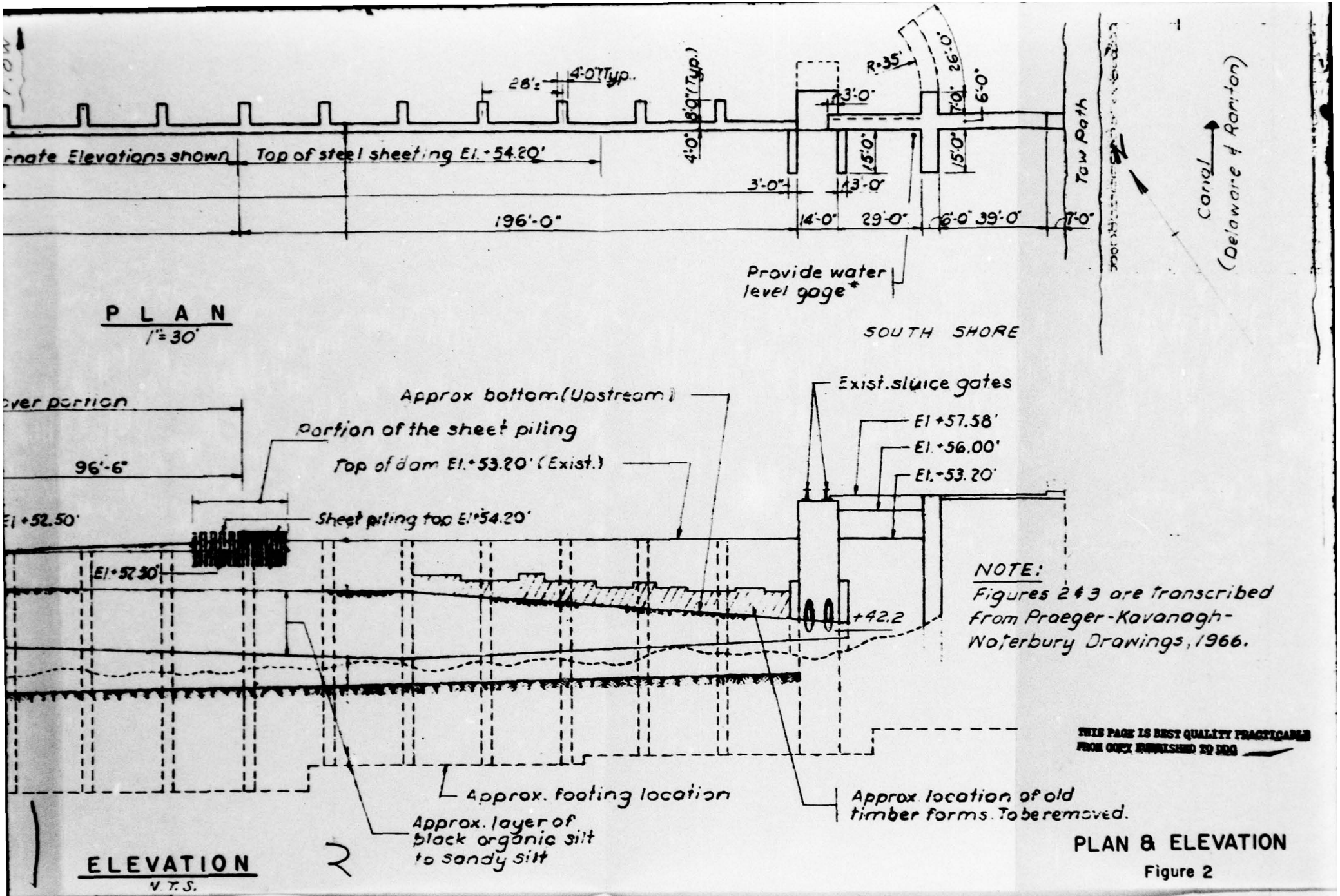


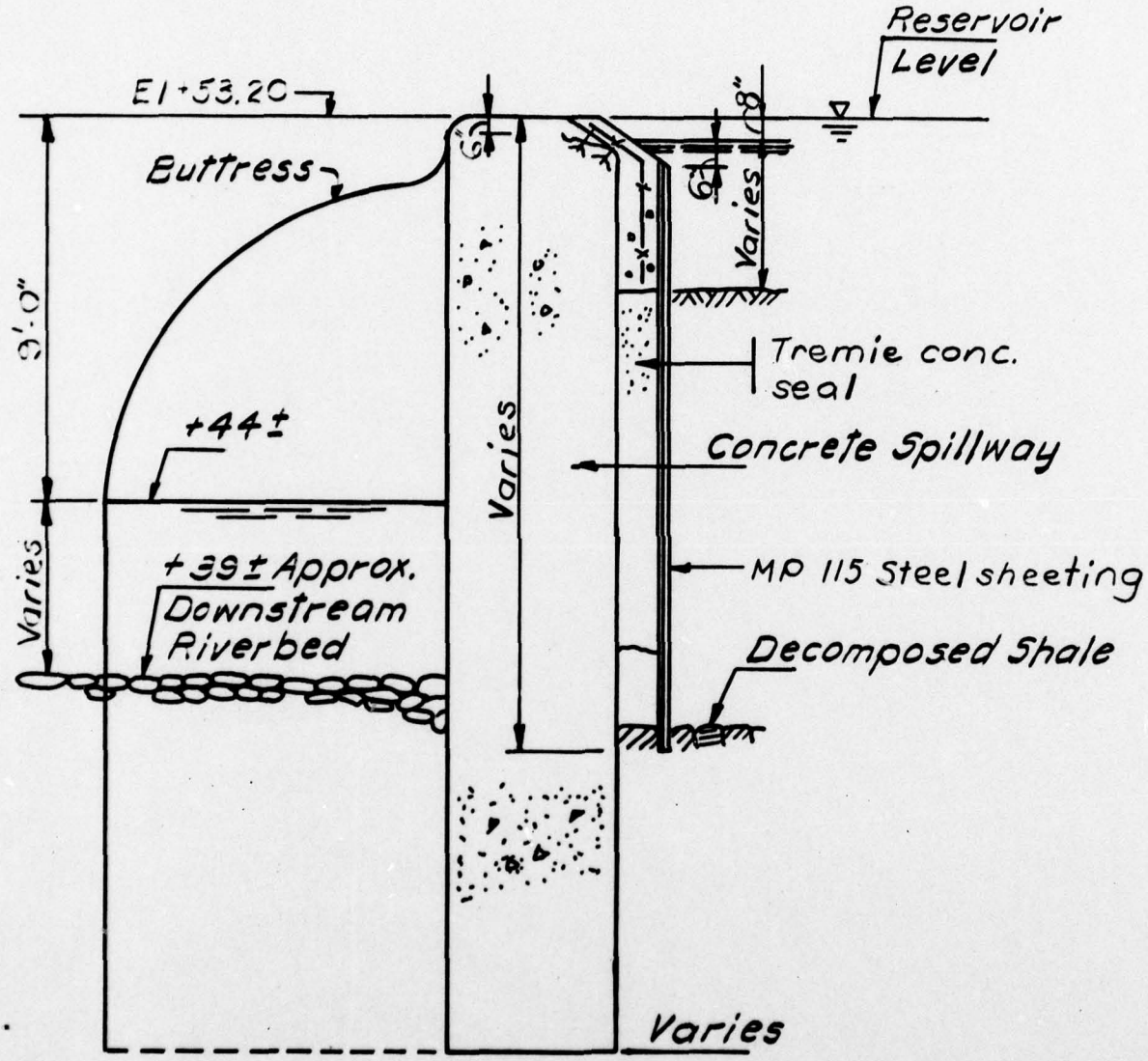
FIGURE 1
REGIONAL
VICINITY MAP
SCALE 1:24,000


Provide water level gage.
B
Flow
Aeration Equip.
6'-0"
3'-0"
Top of steel sheeting El.+54.20'
Drive steel sheet piles to alternate
575'-0"
54'-0"
186'-0"
193'-0"
B
NOTE:
For Section B-B,
see Figure 3.
NORTH SHORE
New V-shaped spill-over p
Exist top of wall El.+52.03
at spill over section.
Approx bottom (Downstream)
El.+53.20'
El.+52.5
Water Level El.+52.50'±
(upstream)
Exist. timber topping
Water Level El.+44.20±
(Downstream)
Approx location of
decomposed shale
Approx. layer of
sand & gravel



PLAN & ELEVATION

Figure 2



SECTION B-B
No Scale

TYPICAL SPILLWAY SECTION

Figure 3

Check List
Visual Inspection
Phase 1

Name Dam Carnegie Lake Dam County Mercer State New Jersey Coordinators NJDEP

Date(s) Inspection 12/7/29/78 1/24/2/8/79 Weather Overcast Temperature 50°

Pool Elevation at Time of Inspection + 53.6 M.S.L. (at Dec. 7 and Dec. 29) Tailwater at Time of Inspection + 44.7 M.S.L.

Inspection Personnel:

Tom Chapter
Richard Lang
K. Jolls
Chhoeur Chhut
Eric Simone
D. Mulligan
Linda Baines

Tom Chapter Recorder

Dam No. 00150

CONCRETE/MASONRY DAMS

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
SEE PAGE ON LEAKAGE	Damp area noted at toe of embankment behind left wingwall.	Entire spillway submerged.
STRUCTURE TO ABUTMENT/EMBANKMENT JUNCTIONS	Heavy erosion behind left wingwall.	
DRAINS	None observed.	
WATER PASSAGES	Sluice gates submerged and not visible - spillway crest appears satisfactory where visible.	All concrete work on spillway and buttresses was refurbished in 1966.
FOUNDATION	Dam built on shale bedrock.	Uniform flow over entire length of spillway. No indications of differential settlement or movement noted.

CONCRETE/MASONRY DAMS

VISUAL EXAMINATION OF	OBERSVATIONS	REMARKS OR RECOMMENDATIONS
SURFACE CRACKS CONCRETE SURFACES	Slight surface deterioration of the left abutment. Light surface cracking and efflorescence noted on right wingwall.	Left retaining wall spalled along leading edge. (See photo). Efflorescence and spalling evident on left wingwall.
STRUCTURAL CRACKING	Severe horizontal cracking on left wingwall.	(See photo) - Spalling and cracking at foot of left retaining wall aided by tree growth. Vegetation should be removed.
VERTICAL AND HORIZONTAL ALIGNMENT	Satisfactory	No differential movement or settlement noted.
MONOLITH JOINTS	N/A	
CONSTRUCTION JOINTS	No movement noted along joints.	

EMBANKMENT

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
SURFACE CRACKS	Horizontal erosion cracks above eroded surfaces of left bank.	
UNUSUAL MOVEMENT OR CRACKING AT OR BEYOND THE TOE	None observed.	
SLOUGHING OR EROSION OF EMBANKMENT AND ABUTMENT SLOPES	Heavy erosion of bank behind left wingwall and retaining wall.	Should be backfilled and vegetation removed from vicinity of dam.
VERTICAL AND HORIZONTAL ALINEMENT OF THE CREST	Satisfactory	
RIPRAP FAILURES	N/A	No riprap stone on dam.

EMBANKMENT

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
JUNCTION OF EMBANKMENT AND ABUTMENT, SPILLWAY AND DAM	Erosion at junction of left wingwall and bank.	Heavy tree growth on both embankments.
ANY NOTICEABLE SEEPAGE	Light seepage at toe of left bank.	
STAFF GAGE AND RECORDER	N/A	Two stage recorders are located downstream on the D & R Canal.
DRAINS	N/A	

OUTLET WORKS

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
CRACKING AND SPALLING OF CONCRETE SURFACES IN OUTLET CONDUIT	Light surface cracking and spalling on gate structure.	
INTAKE STRUCTURE	N/A	
OUTLET STRUCTURE	Satisfactory	
OUTLET CHANNEL	Satisfactory - flows directly to natural channel of Millstone River.	
EMERGENCY GATE	None	

UNGATED SPILLWAY

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
CONCRETE WEIR	Appears in good condition. Branches and bushes accumulated at the V-notch.	
APPROACH CHANNEL	Appears in good condition.	Dredging carried out in 1973-74. Aeration is used to de-ice the spillway.
DISCHARGE CHANNEL	Appears in good condition.	Water discharges into the reservoir of Kingston Mill Dam.
BRIDGE AND PIERS	None	

GATED SPILLWAY

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
CONCRETE SILL	N/A	
APPROACH CHANNEL	N/A	
DISCHARGE CHANNEL	N/A	
BRIDGE AND PIERS	N/A	
GATES AND OPERATION EQUIPMENT	N/A	

INSTRUMENTATION

VISUAL EXAMINATION	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
MONUMENTATION/SURVEYS	Water quality sampling station .2 miles downstream at Linden Highway Bridge. 2 water-stage recorders on right bank of D & R Canal adjacent to dam. Canal and Millstone River are interconnected 500 feet above dam.	
OBSERVATION WELLS	N/A	
WEIRS	N/A	
PIEZOMETERS	N/A	
OTHER	N/A	

RESERVOIR

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
SLOPES	Gently sloping on left side. Right side separated from D & R Canal by flat, narrow, treed towpath.	
SEDIMENTATION	Light.	The lake was dredged in 1973-74. Records of dredging can be found at Princeton University's Engineer's office. Dredgings were carried down in average to 6-8 feet.

DOWNSTREAM CHANNEL

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
CONDITION (OBSTRUCTIONS, DEBRIS, ETC.)	Refer to previous comments on discharge channel in section for ungated spillway.	Kingston Mill Dam immediately downstream. Old Route 27 road bridge may constrict channel 250' below the Mill Dam.
SLOPES	Steeper and higher on left. Narrow flat towpath along right side of river.	
APPROXIMATE NO. OF HOMES AND POPULATION	Several residences and commercial properties immediately downstream along river bank.	

CHECK LIST
ENGINEERING DATA
DESIGN, CONSTRUCTION, OPERATION

ITEM	REMARKS
PLAN OF DAM	- Original construction plans not available. - Plans of reconditioning of dam, by F. S. Tainter & Parsons, Klapp, Brickerhoff & Douglas, in 1930. - 2 sheets of plan, elevation of downstream of dam and details for repair work, prepared by Praeger-Kavanagh-Waterbury in 1966. - Plan of soundings taken after dredging prepared in 1973.
REGIONAL VICINITY MAP	Available; USGS quad sheets
CONSTRUCTION HISTORY	Available (see above)
TYPICAL SECTIONS OF DAM	Available (see above)
HYDROLOGIC/HYDRAULIC DATA	Not available
OUTLETS - PLAN	Available
- DETAILS	Not available
-CONSTRAINTS	Not available
-DISCHARGE RATINGS	Not available
RAINFALL/RESERVOIR RECORDS	Not available

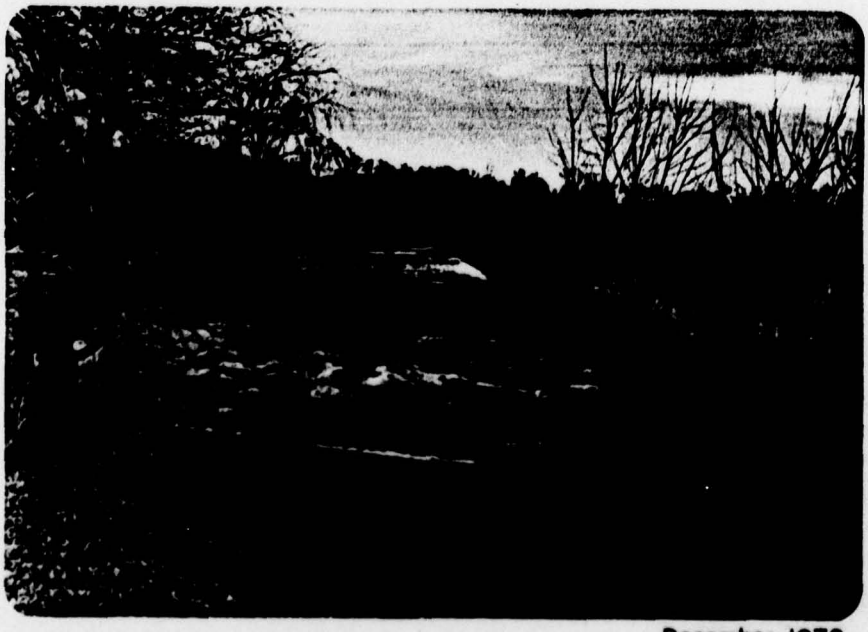
ITEM	REMARKS
DESIGN REPORTS	Not available
GEOLOGY REPORTS	Soil & bedrock description from 1966 repair plans.
DESIGN COMPUTATIONS	Spillway capacity computation done in 1966 by Praegor-Kavanah-Waterbury.
HYDROLOGY & HYDRAULICS	" " " " " " " " " "
DAM STABILITY	None
SEEPAGE STUDIES	None
MATERIALS INVESTIGATIONS	N/A
BORING RECORDS	On 1966 repair plans
LABORATORY	None
FIELD	None
POST-CONSTRUCTION SURVEYS OF DAM	Not available
BORROW SOURCES.	N/A

ITEM	REMARKS
MONITORING SYSTEMS	No mechanical or automatic system. But Princeton University has a plan of inspection to monitor the dam after every storm.
MODIFICATIONS	Available at Princeton University
HIGH POOL RECORDS	Available at Princeton University
POST CONSTRUCTION ENGINEERING STUDIES AND REPORTS	None
PRIOR ACCIDENTS OR FAILURE OF DAM DESCRIPTION REPORTS	None
MAINTENANCE OPERATION RECORDS	Available at Princeton University

ITEM	REMARKS
SPILLWAY PLAN	Available
SECTIONS	Available
DETAILS	Available
OPERATING EQUIPMENT PLANS & DETAILS	N/A for the aeration system.

December, 1978

View of crest from right abutment



December, 1978

Carnegie Lake Dam

December, 1978

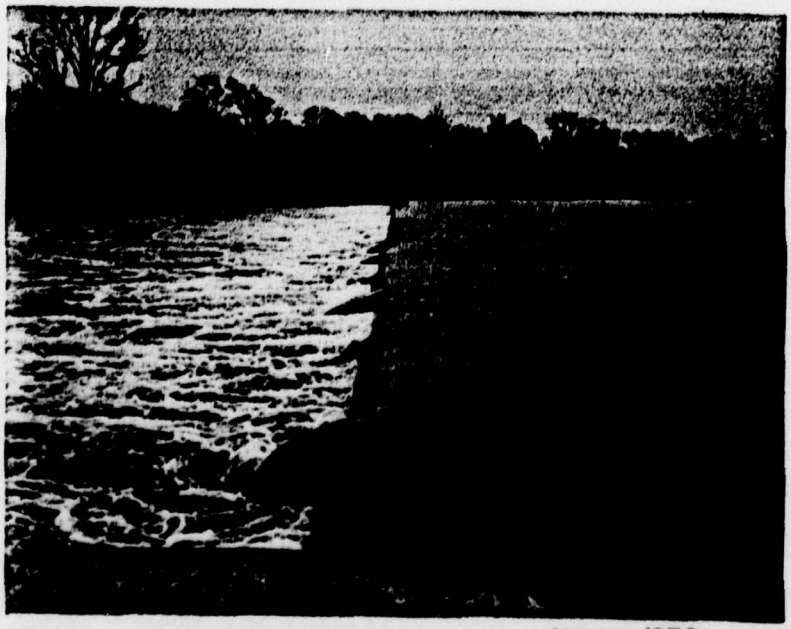
View of crest from left abutment

December, 1978

View upstream

December, 1978

Erosion behind left abutment



January, 1979

View of crest after heavy rainstorm

September, 1978

View of Rt. 27 bridge approx. 1200' downstream from dam

January, 1979

View of Rt. 27 bridge after heavy rainstorm

December, 1978

View of Kingston bridge approx. 1000' downstream from dam

January, 1979

Kingston bridge after heavy rainstorm

September, 1978

View of Kingston Mill Dam downstream from study dam

January, 1979

View after heavy rainstorm

Dam No. 00150

CHECK LIST
HYDROLOGIC AND HYDRAULIC DATA
ENGINEERING DATA

DRAINAGE AREA CHARACTERISTICS: 159.1 square miles

ELEVATION TOP NORMAL POOL (STORAGE CAPACITY): + 53.2 MSL (1344 acre-feet)

ELEVATION TOP FLOOD CONTROL POOL (STORAGE CAPACITY): N/A

ELEVATION MAXIMUM DESIGN POOL: + 56.4 MSL

ELEVATION TOP DAM: + 57.2 MSL

CREST:

a. Elevation + 53.2 feet
b. Type concrete slab and buttress
c. Width 4 feet
d. Length 575 feet
e. Location Spillover 193' long V-notch weir center of dam
f. Number and Type of Gates None

OUTLET WORKS:

a. Type 2 36" dia. CI pipes
b. Location Right abutment
c. Entrance inverts 42.2 ±
d. Exit inverts 42.2 ±
e. Emergency draindown facilities Same as above

HYDROMETEOROLOGICAL GAGES: None at dam

a. Type
b. Location
c. Records

MAXIMUM NON-DAMAGING DISCHARGE: Overtopping discharge of 14,420 ± CFS

BY. D J M DATE 1-79 **LOUIS BERGER & ASSOCIATES INC.** SHEET NO. A1 OF
CHKD. BY ____ DATE ____ CARNEGIE LAKE DAM INSPECTION PROJECT C-227
SUBJECT ____

SNYDER COEFFICIENTS (FROM CORPS OF ENGINEERS)

$C_t = 2.0$

$640\, C_p = 400$

$\therefore C_p = 0.63$

Length of longest watercourse $L \approx 21.93$ miles

Length along watercourse to centroid $L_c \approx 10.4$ miles

$T_p = 2.0 (21.93 \times 10.4)^{0.3}$ $\quad (= C_t (L L_c)^{0.3})$

$= 10.2$ hours

PRECIPITATION

PMF for 200 sq miles & 24 hours duration = 23"

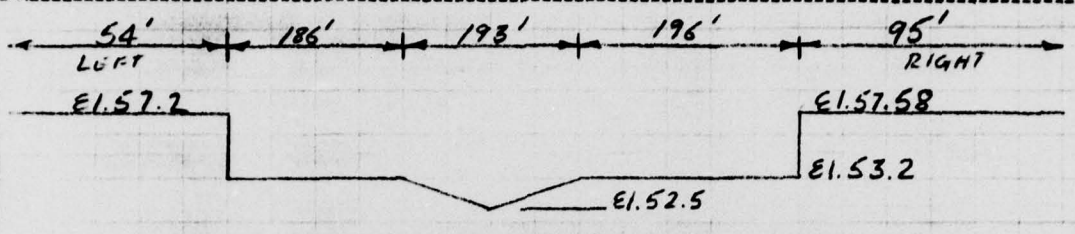
Maximum	6 hour	percentage	= 86 %
"	12 "	"	94 %
"	24 "	"	104 %

BY D. J. M. DATE 1-79
CHKD. BY _____ DATE _____
SUBJECT _____

LOUIS BERGER & ASSOCIATES INC.

CARNEGIE LAKE DAM INSPECTION

SHEET NO. A2 OF _____
PROJECT C-227

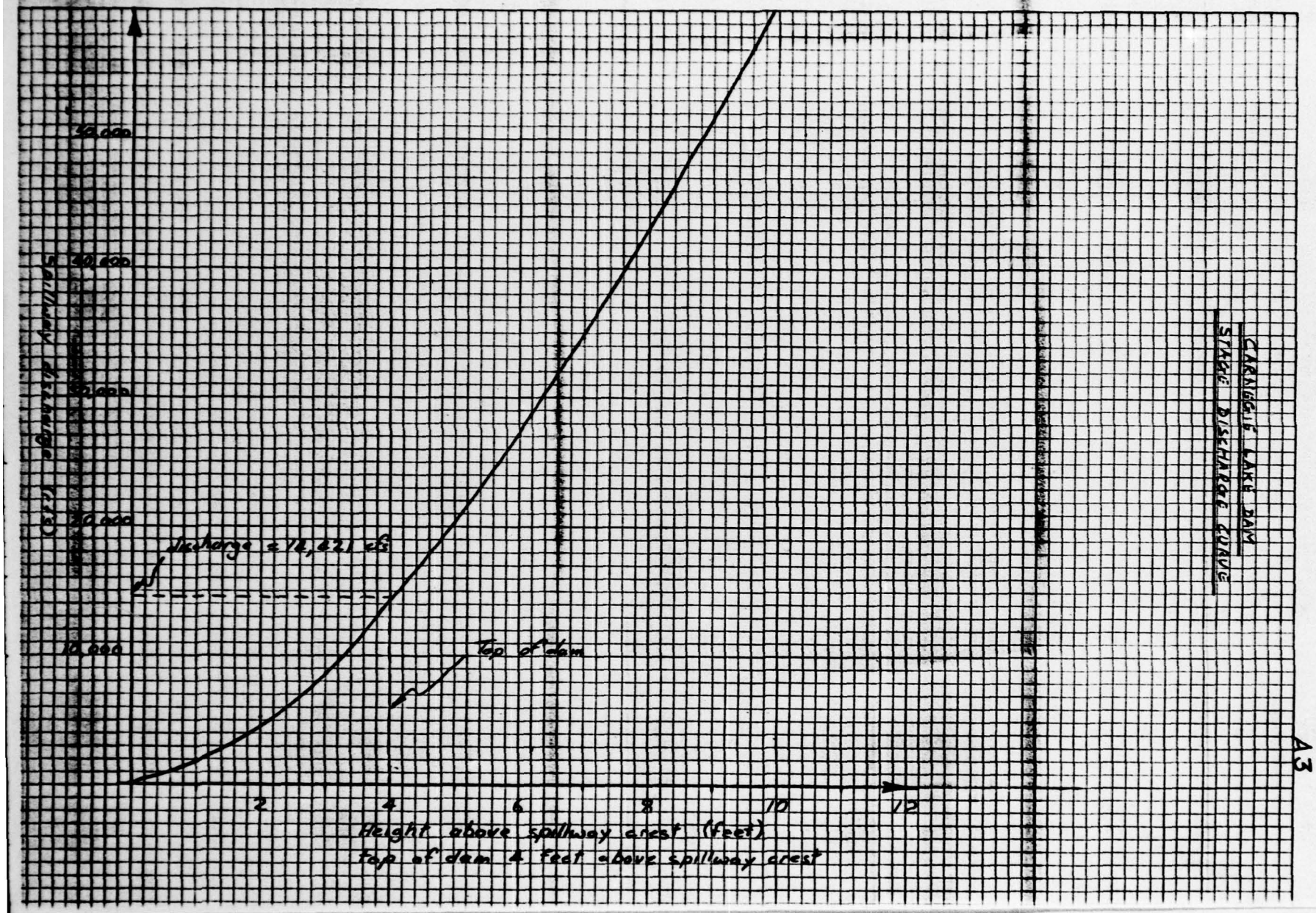


OO - El. 45.2

flow through V notch ≈ 193 × 3 × 0.35$^{1.5}$ ≈ 120 cfs Q El 53.2

	Over Spillway L = 382'			Over Notch L = 193'			OVER DAM LEFT L = 54'			OVER DAM RIGHT L = 95'		
H	C	Q		H	C	Q	H	C	Q	H	C	Q
1	3.0	1146		1.36	3.0	908						
2	3.0	3241		2.35	3.0	2086						
3	3.0	5955		3.35	3.0	3550						
4	3.0	9168		4.35	3.0	5253						
5	3.0	12813		5.35	3.0	7165	1	2.8	151	0.62	2.8	130
6	3.0	16843		6.35	3.0	9265	2	2.8	428	1.62	2.8	548
7	3.0	21224		7.35	3.0	11537	3	2.8	786	2.62	2.8	1128
8	3.0	25931		8.35	3.0	13970	4	2.8	1210	3.62	2.8	1832
9	3.0	30942		9.35	3.0	16554	5	2.8	1690	4.62	2.8	2641
10	3.0	36239		10.35	3.0	19274	6	2.8	2222	5.62	2.8	3544
11	3.0	41809		11.35	3.0	22140	7	2.8	2800	6.62	2.8	4531

H	Height above spillway crest	Σ Q	
1	1	2054	
2	2	5327	
3	3	9505	
4	4	14421	→ max non damaging discharge
5	5	20259	
6	6	27084	
7	7	34675	
8	8	42943	
9	9	51827	
10	10	61299	
11	11	71280	



CARNEGIE LAKE DAM
STAGE DISCHARGE CURVE

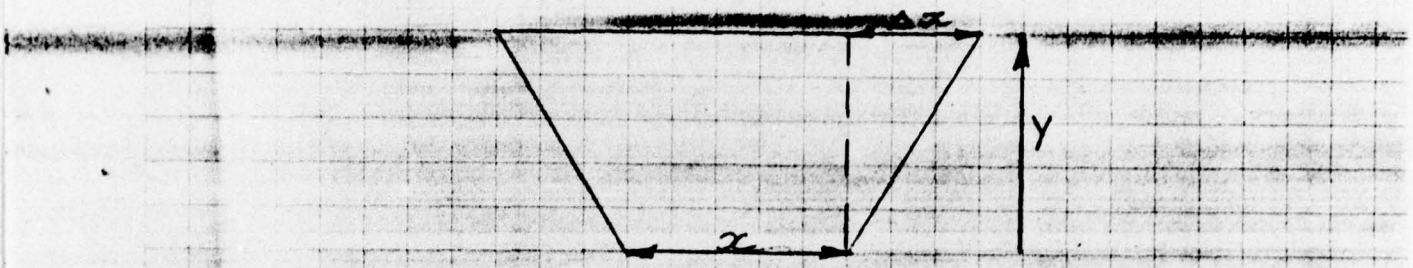
BY D.J.M. DATE 1-79
CHKD. BY _____ DATE _____
SUBJECT _____

LOUIS BERGER & ASSOCIATES INC.

CARNEGIE LAKE DAM INSPECTION

SHEET NO. A4 OF _____
PROJECT C227

AREA OF LAKE @ El. 53.2 ≈ 245 acres
AREA @ El. 57.2 ≈ 1746 acres
AREA @ El. 60.0 ≈ 2796 acres



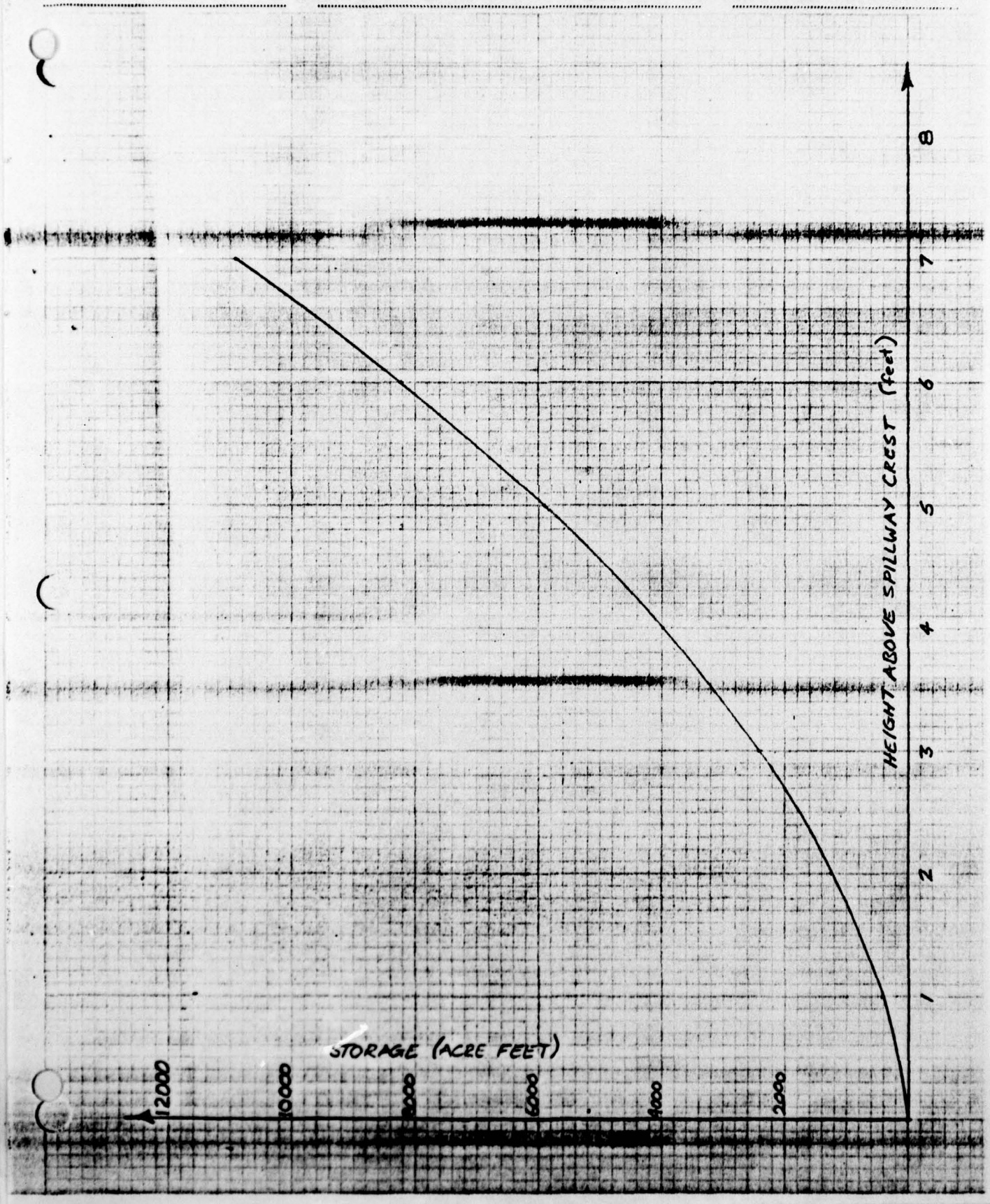
Increment in volume $\Delta V = (x+\Delta x)y$

HEIGHT ABOVE CREST (FEET)	STORAGE ACRE FEET
1	433
2	1241
3	2424
4	3982
5	5916
6	8224
7	10908
8	13966
9	17400
10	21208
11	

BY D J M DATE 1-79
CHKD. BY DATE

SUBJECT STAGE STORAGE CURVE
CARNEGIE LAKE DAM INSPECTION

SHEET NO. A5 OF
JOB NO. C227



BY D.J.M DATE 3-19 **LOUIS BERGER & ASSOCIATES INC.** SHEET NO. A6 OF

CHKD. BY DATE CARNEGIE LAKE DAM INSPECTION PROJECT C-227

SUBJECT

Summary of storage and discharge data for HEC computer program

Height above Spillway crest (feet)	Surcharge Storage (acre feet)	Discharge (cfs)
0	0	0
2	1241	5327
3	2424	9505
4	3982	14421
5	5916	20259
6	8224	27084
7	10908	34675
8	13966	42943
9	17400	51827
10	21208	61284

BY D.J.M. DATE 3-79 **LOUIS BERGER & ASSOCIATES INC.** SHEET NO. A7 OF
CHKD. BY ____ DATE ____ CARNEGIE LAKE DAM INSPECTION PROJECT C227
SUBJECT ____

GENERAL:

Elevation @ top of dam = +57.2
Elevation @ recreation pool = +53.2

Surcharge storage @ El. 57.2 = 3,982 acre feet
Normal pool storage = 1,344 " "

∴ Σ storage @ El. 57.2 = 5,326 acre feet

Max non damaging discharge = 14,420 cfs

length of spillway = 575' ✓

total length of dam = 724'

BY. D.J.M. DATE 3-79 **LOUIS BERGER & ASSOCIATES INC.** SHEET NO. A8 OF

CHKD. BY. DATE CARNEGIE LAKE DAM INSPECTION PROJECT 6227

SUBJECT APPROXIMATE DRAWDOWN CALCULATIONS

DRAWDOWN :

i) Assume tailwater of 5' ∴ available head = 5'

take drawdown under average head of 2.5'

$Q = 0.55 \times 14.14 \sqrt{64.32 \times 2.5} \approx 99$ cfs

ii) Assume inflow to the reservoir of 1 cfs / sq mile gives inflow of 159 cfs

∴ outflow is less than inflow thus the lake will not draw down

If there were no tailwater

$Q = 0.55 \times 14.14 \sqrt{64.32 \times 10} = 197$ cfs

Resultant outflow = 197 - 159 = 38 cfs

Volume = 58,544,640 ft³

∴ time = $\frac{58,544,640}{38 \times 3600 \times 24} \approx$ 18 days

CARNEGIE LAKE DAM INSPECTION NORTH GROUP C227
BY D.J.MULLIGAN
JANUARY 1979

JOB SPECIFICATION

NQ	NHR	NMIN	IDAY	IHR	IMIN	METRC	IPLT	IPRT	NSTAN
100	1	0	0	0	0	0	0	0	0

JOPER	NWT
5	0

MULTI-PLAN ANALYSES TO BE PERFORMED
NPLAN= 1 NRTIO= 5 LRTIO= 1
RTIOS= 1.00 0.50 0.40 0.20 0.10

********** ********** ********** ********** **********

SUB-AREA RUNOFF COMPUTATION

INFLOW HYDROGRAPH

ISTAG	ICOMP	IECON	ITAPE	JPLT	JPRT	INAME
3	0	0	0	0	0	1

HYDROGRAPH DATA

IHYDG	IUHG	TAREA	SNAP	TRSDA	TRSPC	RATIO	ISNOW	ISAME	LOCAL
1	1	159.10	0.0	159.10	0.0	0.0	0	1	0

PRECIP DATA

SPFE	PMS	R6	R12	R24	R48	R72	R96
0.0	23.00	86.00	94.00	104.00	0.0	0.0	0.0

TRSPC COMPUTED BY THE PROGRAM IS 0.877

LOSS DATA

STRKR	DLTKR	RTIOL	ERAIN	STRKS	RTIOK	STRTL	CNSTL	ALSMX	RTIMP
0.0	0.0	1.00	0.0	0.0	1.00	0.50	0.10	0.0	0.0

UNIT HYDROGRAPH DATA
TP= 10.20 CP=0.63 NTA= 0

RECESSION DATA
STRTQ= 0.0 QRCSN= 0.0 RTIOR= 1.00

APPROXIMATE CLARK COEFFICIENTS FROM GIVEN SNYDER CP AND TP ARE TC=11.21 AND R= 9.22 INTERVALS

UNIT HYDROGRAPH 55 END-OF-PERIOD ORDINATES, LAG= 10.12 HOURS, CP= 0.63 VOL= 1.00

199.	741.	1499.	2374.	3320.	4300.	5195.	5882.	6342.	6569.
6528.	6122.	5512.	4944.	4435.	3979.	3569.	3202.	2872.	2577.
2311.	2074.	1860.	1669.	1497.	1343.	1205.	1081.	969.	870.
780.	700.	628.	563.	505.	453.	407.	365.	327.	293.
263.	236.	212.	190.	170.	153.	137.	123.	110.	99.
89.	80.	71.	64.	58.					

END-OF-PERIOD FLOW

TIME	RAIN	EXCS	COMP Q

BY_____ DATE_____
CHKD. BY_____ DATE_____
SUBJECT_____

LOUIS BERGER & ASSOCIATES INC.

CARNEGIE LAKE DAM

SHEET NO. A10 OF_____
PROJECT C-277

1	0.13	0.00	0.
2	0.13	0.00	0.
3	0.13	0.00	0.
4	0.13	0.01	2.
5	0.13	0.03	14.
6	0.13	0.03	47.
7	0.27	0.17	134.
8	0.27	0.17	325.
9	0.27	0.17	651.
10	0.27	0.17	1128.
11	0.27	0.17	1761.
12	0.27	0.17	2547.
13	1.74	1.64	3759.
14	2.08	1.98	5933.
15	2.60	2.50	9568.
16	6.60	6.50	15839.
17	2.43	2.33	25505.
18	1.91	1.81	37986.
19	0.20	0.10	52221.
20	0.20	0.10	67007.
21	0.20	0.10	81314.
22	0.20	0.10	93898.
23	0.20	0.10	103566.
24	0.20	0.10	109516.
25	0.0	0.0	111441.
26	0.0	0.0	109485.
27	0.0	0.0	103793.
28	0.0	0.0	95720.
29	0.0	0.0	87052.
30	0.0	0.0	78678.
31	0.0	0.0	70995.
32	0.0	0.0	63980.
33	0.0	0.0	57577.
34	0.0	0.0	51745.
35	0.0	0.0	46448.
36	0.0	0.0	41669.
37	0.0	0.0	37380.
38	0.0	0.0	33532.
39	0.0	0.0	30080.
40	0.0	0.0	26984.
41	0.0	0.0	24207.
42	0.0	0.0	21715.
43	0.0	0.0	19480.
44	0.0	0.0	17475.
45	0.0	0.0	15676.
46	0.0	0.0	14062.
47	0.0	0.0	12615.
48	0.0	0.0	11316.
49	0.0	0.0	10152.
50	0.0	0.0	9107.
51	0.0	0.0	8169.
52	0.0	0.0	7328.
53	0.0	0.0	6574.
54	0.0	0.0	5897.
55	0.0	0.0	5290.
56	0.0	0.0	4746.
57	0.0	0.0	4257.
58	0.0	0.0	3819.
59	0.0	0.0	3426.
60	0.0	0.0	3071.
61	0.0	0.0	2753.
62	0.0	0.0	2461.
63	0.0	0.0	2199.
64	0.0	0.0	1964.
65	0.0	0.0	1753.
66	0.0	0.0	1564.
67	0.0	0.0	1394.
68	0.0	0.0	1166.
69	0.0	0.0	944.
70	0.0	0.0	718.

71	0.0	0.0	308.
72	0.0	0.0	156.
73	0.0	0.0	47.
74	0.0	0.0	37.
75	0.0	0.0	28.
76	0.0	0.0	20.
77	0.0	0.0	12.
78	0.0	0.0	6.
79	0.0	0.0	0.
80	0.0	0.0	0.
81	0.0	0.0	0.
82	0.0	0.0	0.
83	0.0	0.0	0.
84	0.0	0.0	0.
85	0.0	0.0	0.
86	0.0	0.0	0.
87	0.0	0.0	0.
88	0.0	0.0	0.
89	0.0	0.0	0.
90	0.0	0.0	0.
91	0.0	0.0	0.
92	0.0	0.0	0.
93	0.0	0.0	0.
94	0.0	0.0	0.
95	0.0	0.0	0.
96	0.0	0.0	0.
97	0.0	0.0	0.
98	0.0	0.0	0.
99	0.0	0.0	0.
100	0.0	0.0	0.
SUM	20.96	18.45	1885192.

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	111441.	105587.	67398.	26183.	1885170.
INCHES		6.17	15.76	18.37	18.37
AC-FT		52384.	133751.	155878.	155880.

HYDROGRAPH AT STA 3 FOR PLAN 1, RTIO 1

0.	0.	0.	2.	14.	47.	134.	325.	651.	1128.
1761.	2547.	3759.	5933.	9568.	15839.	25505.	37986.	52221.	67007.
81314.	93898.	103566.	109516.	111441.	109485.	103793.	95720.	87052.	78678.
70995.	63980.	57577.	51745.	46448.	41669.	37380.	33532.	30080.	26984.
24207.	21715.	19480.	17475.	15676.	14062.	12615.	11316.	10152.	9107.
8169.	7328.	6574.	5897.	5290.	4746.	4257.	3819.	3426.	3071.
2755.	2461.	2199.	1964.	1753.	1564.	1394.	1166.	944.	718.
308.	156.	47.	37.	28.	20.	12.	6.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	111441.	105587.	67398.	26183.	1885170.

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INCHES			6.17	15.76	18.37		18.37		
AC-FT			52384.	133751.	155878.		155880.		
HYDROGRAPH AT STA 3 FOR PLAN 1, RTIO 2									
0.	0.	0.	1.	7.	24.	67.	163.	326.	564.
880.	1274.	1880.	2967.	4784.	7920.	12753.	18993.	26110.	33504.
40657.	46749.	51783.	54758.	55720.	54742.	51897.	47860.	43526.	39339.
35498.	31990.	28789.	25872.	23224.	20834.	18690.	16766.	15040.	13492.
12103.	10858.	9740.	8737.	7838.	7031.	6307.	5658.	5076.	4553.
4085.	3664.	3287.	2949.	2645.	2373.	2129.	1910.	1713.	1536.
1377.	1231.	1100.	982.	877.	782.	697.	583.	472.	359.
154.	78.	23.	18.	14.	10.	6.	3.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	55720.	52793.	33699.	13091.	942596.
INCHES		3.09	7.88	9.19	9.19
AC-FT		26192.	66876.	77940.	77941.

HYDROGRAPH AT STA 3 FOR PLAN 1, RTIO 3

0.	0.	0.	1.	6.	19.	54.	130.	261.	451.
704.	1019.	1504.	2373.	3827.	6336.	10202.	15154.	20886.	26803.
32526.	37559.	41426.	43806.	44576.	43794.	41517.	38288.	34821.	31471.
28398.	25592.	23031.	20698.	18579.	16667.	14952.	13413.	12032.	10794.
9683.	8686.	7792.	6990.	6270.	5625.	5046.	4527.	4061.	3643.
3268.	2931.	2630.	2359.	2116.	1898.	1703.	1528.	1370.	1228.
1101.	984.	880.	786.	701.	626.	558.	497.	378.	287.
123.	63.	19.	15.	11.	8.	5.	2.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	44576.	42235.	26959.	10473.	754076.
INCHES		2.47	6.31	7.35	7.35
AC-FT		20954.	53501.	62352.	62352.

HYDROGRAPH AT STA 3 FOR PLAN 1, RTIO 4

0.	0.	0.	0.	3.	9.	27.	65.	130.	226.
352.	509.	752.	1187.	1914.	3168.	5101.	7597.	10444.	13401.
16263.	18780.	20713.	21903.	22288.	21897.	20759.	19144.	17410.	15736.
14199.	12796.	11515.	10349.	9290.	8334.	7476.	6706.	6016.	5397.
4841.	4343.	3896.	3495.	3135.	2812.	2523.	2263.	2030.	1821.
1634.	1466.	1315.	1179.	1058.	949.	851.	764.	685.	614.
551.	492.	440.	393.	351.	313.	279.	233.	189.	144.
62.	31.	9.	7.	6.	4.	2.	1.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	22288.	21117.	13480.	5237.	377037.
INCHES		1.23	3.15	3.67	3.67
AC-FT		10477.	26750.	31176.	31176.

HYDROGRAPH AT STA 3 FOR PLAN 1, RTIO 5

0.	0.	0.	0.	1.	5.	13.	33.	65.	113.
174.	255.	376.	593.	957.	1584.	2551.	3799.	5222.	6701.
8131.	9390.	10357.	10952.	11144.	10948.	10379.	9572.	8705.	7858.
7100.	6398.	5758.	5174.	4645.	4167.	3738.	3353.	3008.	2698.
2421.	2171.	1948.	1747.	1568.	1406.	1261.	1132.	1015.	911.
817.	733.	657.	590.	529.	475.	426.	382.	343.	307.

275.	246.	220.	196.	175.	156.	139.	117.	94.	72.
31.	16.	5.	4.	3.	2.	1.	1.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	11144.	10559.	6740.	2618.	188518.
INCHES		0.62	1.58	1.84	1.84
AC-FT		5238.	13375.	15588.	155888.

****

HYDROGRAPH ROUTING

ROUTING THROUGH RESERVOIR

ISTAQ	ICOMP	IECON	ITAPE	JPLT	JPRT	INAME
33	1	0	0	0	0	1

ROUTING DATA

QLOSS	CLOSS	AVG	IRES	ISAME
0.0	0.0	0.0	1	0

NSTPS	NSTOL	LAG	AMSKK	X	TSK	STORA
1	0	0	0.0	0.0	0.0	0.

STORAGE=	0.	1241.	2424.	3982.	5916.	8224.	10908.	13966.	17400.	21208.
OUTFLOW=	0.	5327.	9505.	14421.	20259.	27084.	34675.	42943.	51827.	61284.

STATION 33, PLAN 1, RTIO 1

0.	0.	0.	0.	3.	11.	35.	94.	213.	417.
726.	1157.	1758.	2689.	4214.	6548.	10085.	15057.	21695.	29641.
38940.	48496.	57968.	67010.	75101.	81683.	86329.	88828.	89304.	88106.
85636.	82258.	78259.	73867.	69256.	64566.	59904.	55353.	50958.	46610.
42535.	38601.	34982.	31541.	28409.	25514.	22862.	20489.	18330.	16400.
14678.	13090.	11674.	10419.	9285.	8199.	7257.	6437.	5720.	5047.
4404.	3863.	3401.	3003.	2656.	2357.	2093.	1848.	1609.	1374.
1115.	849.	624.	448.	323.	233.	168.	120.	85.	59.
41.	29.	20.	14.	10.	7.	5.	3.	2.	2.
1.	1.	1.	0.	0.	0.	0.	0.	0.	0.

STOR

0.	0.	0.	0.	1.	3.	8.	22.	50.	97.
169.	269.	410.	626.	982.	1587.	2608.	4193.	6401.	9199.
12485.	16113.	19873.	23514.	26772.	29422.	31293.	32299.	32491.	32008.
31014.	29653.	28043.	26275.	24418.	22529.	20652.	18820.	17056.	15383.
13815.	12360.	11022.	9800.	8692.	7693.	6796.	5994.	5277.	4638.
4067.	3560.	3111.	2714.	2362.	2054.	1787.	1555.	1352.	1176.
1026.	900.	792.	700.	619.	549.	487.	430.	379.	320.
260.	198.	145.	104.	75.	54.	39.	28.	20.	14.
10.	7.	5.	3.	2.	2.	1.	1.	1.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	89304.	86743.	64002.	26179.	1885159.
INCHES		5.07	14.97	18.37	18.37
AC-FT		43035.	127012.	155859.	155879.

BY_____DATE_____ **LOUIS BERGER & ASSOCIATES INC.** SHEET NO. A-14 OF___

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SUBJECT_____

20459.	25543.	30589.	35310.	39315.	42514.	44614.	45634.	45646.	44832.
43400.	41477.	39249.	36853.	34368.	31786.	29269.	26845.	24462.	22241.
20183.	18253.	16489.	14881.	13378.	12007.	10776.	9670.	8591.	7629.
6786.	6044.	5390.	4717.	4139.	3648.	3227.	2863.	2546.	2268.
2024.	1807.	1613.	1441.	1287.	1149.	1026.	909.	794.	680.
552.	421.	309.	223.	160.	116.	83.	60.	42.	29.
21.	14.	10.	7.	5.	3.	2.	2.	1.	1.
1.	0.	0.	0.	0.	0.	0.	0.	0.	0.

STOR

0.	0.	0.	0.	0.	1.	4.	11.	25.	49.
85.	135.	205.	313.	491.	789.	1278.	2029.	3079.	4415.
5984.	7705.	9463.	11143.	12624.	13807.	14613.	15006.	15011.	14696.
14143.	13424.	12600.	11714.	10799.	9886.	8997.	8143.	7337.	6586.
5891.	5251.	4667.	4134.	3651.	3217.	2827.	2476.	2165.	1893.
1654.	1444.	1259.	1099.	964.	850.	752.	667.	593.	528.
471.	421.	376.	336.	300.	268.	239.	212.	185.	158.
129.	98.	72.	52.	37.	27.	19.	14.	10.	7.
5.	3.	2.	2.	1.	1.	1.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	45646.	44440.	32294.	13090.	942594.
INCHES		2.60	7.55	9.18	9.19
AC-FT		22048.	64088.	77930.	77941.

STATION 33, PLAN 1, RTIO 3

0.	0.	0.	0.	1.	4.	14.	38.	85.	167.
291.	463.	703.	1075.	1686.	2709.	4384.	6648.	9545.	12844.
16636.	20710.	24801.	28618.	31877.	34453.	36110.	36873.	36809.	36073.
34839.	33204.	31343.	29359.	27325.	25222.	23172.	21214.	19348.	17568.
15958.	14456.	13023.	11724.	10549.	9485.	8428.	7501.	6684.	5962.
5323.	4653.	4089.	3606.	3195.	2837.	2525.	2251.	2009.	1795.
1605.	1436.	1284.	1148.	1026.	917.	819.	726.	635.	544.
442.	337.	247.	178.	128.	92.	67.	48.	34.	23.
16.	11.	8.	6.	4.	3.	2.	1.	1.	1.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

STOR

0.	0.	0.	0.	0.	1.	3.	9.	20.	39.
68.	108.	164.	251.	393.	631.	1021.	1615.	2437.	3482.
4716.	6049.	7452.	8766.	9919.	10830.	11439.	11721.	11697.	11425.
10969.	10486.	9730.	9028.	8309.	7594.	6901.	6239.	5614.	5031.
4491.	3993.	3539.	3127.	2755.	2418.	2119.	1856.	1625.	1421.
1240.	1084.	953.	841.	744.	661.	588.	524.	468.	418.
374.	335.	299.	267.	239.	214.	191.	169.	148.	127.
103.	78.	58.	41.	30.	22.	15.	11.	8.	5.
4.	3.	2.	1.	1.	1.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	36873.	35859.	25911.	10472.	754074.
INCHES		2.10	6.06	7.35	7.35
AC-FT		17791.	51419.	62344.	62352.

STATION 33, PLAN 1, RTIO 4

0.	0.	0.	0.	1.	2.	7.	19.	43.	83.
145.	231.	352.	538.	843.	1354.	2192.	3445.	5125.	6887.
8911.	10953.	12982.	14884.	16484.	17728.	18526.	18842.	18717.	18241.
17515.	16624.	15633.	14590.	13496.	12416.	11375.	10387.	9453.	8499.
7638.	6862.	6164.	5535.	4964.	4423.	3924.	3473.	3077.	2688.

BY_____DATE_____ **LOUIS BERGER & ASSOCIATES INC.** SHEET NO. A-15 OF_____

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SUBJECT_____

2399.	2143.	1916.	1715.	1535.	1375.	1232.	1104.	990.	887.
795.	713.	638.	572.	511.	457.	409.	363.	317.	272.
221.	168.	124.	89.	64.	46.	33.	24.	17.	12.
8.	6.	4.	3.	2.	1.	1.	1.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

STOR

0.	0.	0.	0.	0.	1.	2.	4.	10.	19.
34.	54.	82.	125.	196.	316.	511.	802.	1194.	1683.
2255.	2883.	3526.	4135.	4665.	5077.	5342.	5447.	5405.	5248.
5007.	4712.	4383.	4038.	3689.	3346.	3017.	2703.	2409.	2139.
1895.	1676.	1478.	1300.	1142.	1007.	891.	790.	703.	626.
559.	499.	446.	399.	358.	320.	287.	257.	231.	207.
185.	166.	149.	133.	119.	107.	95.	84.	74.	63.
51.	39.	29.	21.	15.	11.	8.	6.	4.	3.
2.	1.	1.	1.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

		PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
	CFS	18842.	18262.	13075.	5236.	377036.
	INCHES		1.07	3.06	3.67	3.67
	AC-FT		9060.	25948.	31172.	31176.

STATION 33, PLAN 1, RTIO 5

0.	0.	0.	0.	0.	1.	4.	9.	21.	42.
73.	116.	176.	269.	421.	677.	1096.	1722.	2562.	3587.
4740.	5855.	6879.	7840.	8657.	9266.	9611.	9695.	9567.	9247.
8798.	8276.	7716.	7143.	6574.	6022.	5495.	4938.	4409.	3940.
3524.	3154.	2824.	2530.	2267.	2032.	1822.	1633.	1465.	1313.
1178.	1057.	948.	850.	762.	684.	613.	550.	494.	443.
397.	356.	319.	286.	256.	229.	204.	181.	158.	136.
110.	84.	62.	44.	32.	23.	17.	12.	8.	6.
4.	3.	2.	1.	1.	1.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

STOR

0.	0.	0.	0.	0.	0.	1.	2.	5.	10.
17.	27.	41.	63.	98.	158.	255.	401.	597.	836.
1104.	1391.	1680.	1953.	2184.	2356.	2458.	2484.	2444.	2351.
2224.	2076.	1917.	1755.	1594.	1438.	1288.	1150.	1027.	918.
821.	735.	658.	589.	528.	473.	424.	381.	341.	306.
274.	246.	221.	198.	178.	159.	143.	128.	115.	103.
93.	83.	74.	67.	60.	53.	48.	42.	37.	32.
26.	20.	14.	10.	7.	5.	4.	3.	2.	1.
1.	1.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

		PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
	CFS	9695.	9364.	6573.	2618.	188517.
	INCHES		0.55	1.54	1.84	1.84
	AC-FT		4646.	13044.	15586.	15588.

STATION 33, PLAN 1, RTIO 2

0.	0.	0.	0.	1.	6.	18.	47.	106.	208.
361.	578.	877.	1244.	2107.	3386.	5456.	8109.	11573.	15727.

PEAK FLOW SUMMARY FOR MULTIPLE PLAN-RATIO ECONOMIC COMPUTATIONS

OPERATION	STATION	PLAN	RATIOS APPLIED TO FLOWS 1.00	0.50	0.40	0.20	0.10
HYDROGRAPH AT	3	1	111441.	55720.	44576.	22288.	11144.
		2	**********	-0.	-0.	17777152.	**********
ROUTED TO	33	1	89304.	45646.	36873.	18842.	9695.
		2	**********	-0.	-0.	17777152.	**********